Hazard Profile – Volcano

Summary

- The hazard – Washington State has five active volcanoes – Mount Baker, Glacier Peak, Mount Rainier, Mount St. Helens, and Mount Adams. These volcanoes are all capable of generating destructive lahars, ash fall, lava and pyroclastic flows, and debris avalanches. The phenomena that pose the greatest threat are ash fall and lahars. Mount Hood in Oregon also poses a threat to communities along the Washington side of the Columbia River. All of these volcanoes pose a high to very high threat to life, property, the environment, and civil and military aviation in areas more than a few miles from the mountains' slopes.

- Previous occurrences – All five volcanoes have been active in the past 4,000 years, with Mount St. Helens (more than a dozen eruptive events) and Glacier Peak (at least six eruptions) the most active. Mount St. Helens has been the most active in the past 30 years with a massive eruption in 1980, followed by dome building eruptions in the 1980-1986 and 2004-present periods. All volcanoes have had eruptions that generated ash fall and / or lahars in the past 300 years.

- Probability of future events – Washington's volcanoes will erupt again, as shown by recent activity at Mount St. Helens. There is a 1 in 500 probability that portions of 2 counties will receive 10 centimeters (4 inches) or more of volcanic ash from any Cascades volcano in any given year, and a 1 in 1,000 probability that parts or all of 3 more counties will receive that quantity of ash. There is a 1 in 100 annual probability that small lahars or debris flows will impact river valleys below Mount Baker and Rainier, and less than a 1 in 1,000 annual probability that the largest destructive lahars would flow down the slopes of Glacier Peak, Mount Adams, Mount Baker, and Mount Rainier.

- Jurisdictions at greatest risk – Communities to the northeast, east, and southeast of Mount St. Helens are at greatest risk of receiving damaging ash fall. Communities generally to the west and / or south of the volcanoes are at risk to the impact of damaging lahars.

Introduction[1, 2, 3, 4, 5]

A volcano is a vent in the earth's crust through which magma, rock fragments, gases, and ash are ejected from the earth's interior. Over time, accumulation of these erupted products on the earth's surface creates a volcanic mountain.

Washington State has five major volcanoes in the Cascade Range – from north to south they are Mount Baker, Glacier Peak, Mount Rainier, Mount St. Helens and Mount Adams. These mountains are composite or strato-volcanoes, a term for steep-sided, often symmetrical cones constructed of alternating layers of lava flows, ash, and other volcanic debris. Composite volcanoes tend to erupt explosively and pose considerable danger to nearby life and property. In contrast, the gently sloping shield volcanoes, such as those in Hawaii, typically erupt non-explosively, producing fluid lavas that can flow great distances from the active vents. Although Hawaiian-type eruptions may destroy property, they rarely cause death or injury. Young lava-flow volcanoes similar to Hawaiian volcanoes form much of the southern part of the Cascades south of Mount St. Helens and Mt. Adams to the Columbia River.

Volcanoes can lie dormant for centuries between eruptions, and the risk posed by volcanic activity is not always apparent. When Cascade volcanoes do erupt, high-speed avalanches of hot ash and rock called pyroclastic flows, lava flows, and landslides can devastate areas 10 or more miles away, while huge mudflows of volcanic ash and debris called lahars can inundate valleys more than 50 miles downstream. Falling ash from explosive eruptions can disrupt human activities hundreds of miles downwind, and drifting clouds of fine ash can cause severe damage to the engines of jet aircraft hundreds or thousands of miles away.

Washington’s volcanoes will erupt again, as shown by activity at Mount St. Helens, which began another eruptive phase in the fall of 2004. Because people are moving into areas near these mountains at a rapid pace, the state’s volcanoes are among the most dangerous in the United States.

- Mount Baker in Whatcom County erupted in the mid-1800s for the first time in several thousand years. Activity at steam vents in Sherman Crater, near the volcano's summit, increased in 1975 and is still vigorous, but there is no evidence that an eruption is imminent.

- Glacier Peak in Snohomish County has erupted at least six times in the past 4,000 years, the last time about 1700 with ash and steam eruptions and small lahars. An especially powerful series of eruptions about 13,000 years ago deposited volcanic ash at least as far away as Wyoming.

- Mount Rainier in Pierce County is one of the most hazardous volcanoes in the United States. It has produced at least four eruptions and numerous lahars in the past 4,000 years. It is capped by more glacial ice than the rest of the Cascades volcanoes combined, and parts of Rainier's steep slopes have been weakened by hot, acidic volcanic gases and water. These factors make this volcano especially prone to landslides and lahars. More than 150,000 people live on deposits of lahars in river valleys below the volcano.

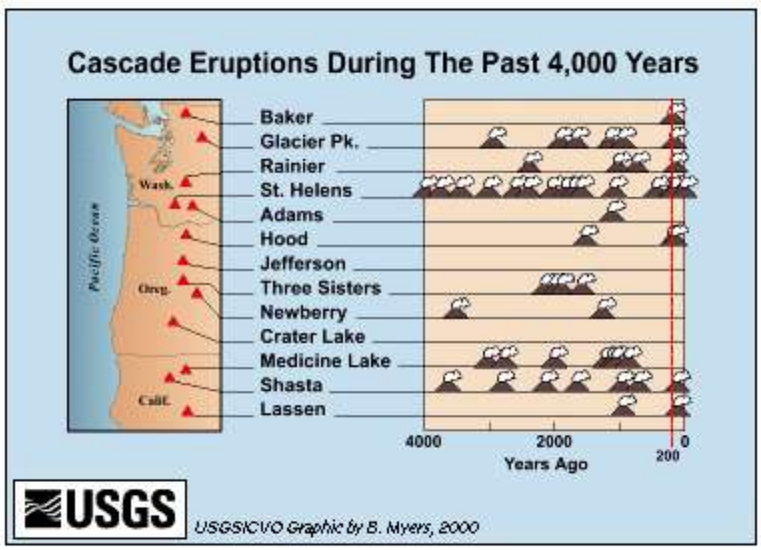
- Mount St. Helens in Skamania County is the youngest, most frequently active, and often the most explosive volcano in the Cascades. During the past 4,000 years, it has produced many lahars and a wide variety of eruptive activity, from relatively quiet outflows of lava to explosive eruptions much larger than that of May 18, 1980. Its current eruption began in September 2004.

- Mount Adams in Yakima and Skamania Counties has produced few eruptions during the past several thousand years. This volcano's most recent activity was a series of small eruptions about 1,000 years ago followed by a debris avalanche and lahar that inundated part of the Trout Lake lowland less than 500 years ago.

The U.S. Geological Survey considers the volcanic threats to civil and military aviation, life, and property posed by Mount St. Helens, Mount Rainier, Mount Baker and Glacier Peak to be very high, the highest classification in an assessment the survey published in April 2005. The same report considers the threat posed by Mount Adams to be high.

Additionally, Oregon's Mount Hood, about 50 miles southeast of Portland, poses some threat to areas of Southwest Washington along the Columbia River. Mount Hood has erupted repeatedly for thousands of years, most recently during two episodes in the past 1,500 years; the last eruption ended shortly before the arrival of Lewis and Clark in 1805. Mount Hood, and other volcanoes in British Columbia, Oregon, and California, can produce tephra which would fall on and affect Washington. The April 2005 USGS assessment states the threat posed by Mount Hood also is very high.

The Hazard



Scientists define a volcano as active if it has erupted in historic time or is seismically or geothermally active. Volcanoes commonly repeat past behavior. Typically, volcanoes provide warning signals before they erupt. As magma pushes its way upward, it moves aside old rocks and produces earthquakes, causing the sides of the volcano to deform. Neither the earthquakes nor the deformation may be apparent to people, but they are detectible with instruments. So are heat and gases from the rising magma which may cause changes in the temperature, discharge rate and composition of hot springs and vapors on the volcano. However, small explosions caused by heated material that contacts groundwater, or landslides and debris flows could occur without warning.

Periods of volcanic unrest typically are times of great uncertainty. Scientists can make only general statements about the probability, types and scale of an impending eruption. Precursory activity can wax and wane, and sometimes die out without leading to an eruption. [6]

Among the effects of volcanic activity are:

- Avalanches of glacial ice, snow, rock and debris from volcanic mountains cause damage down slope and in valleys. Such avalanches can range in size from small movements of loose debris on the surface of a volcano to massive failures of the entire summit or flanks of a volcano such as occurred during the 1980 eruption of Mount St. Helens. They travel rapidly and carry large amounts of material; many, especially smaller ones, can occur with little or no warning.

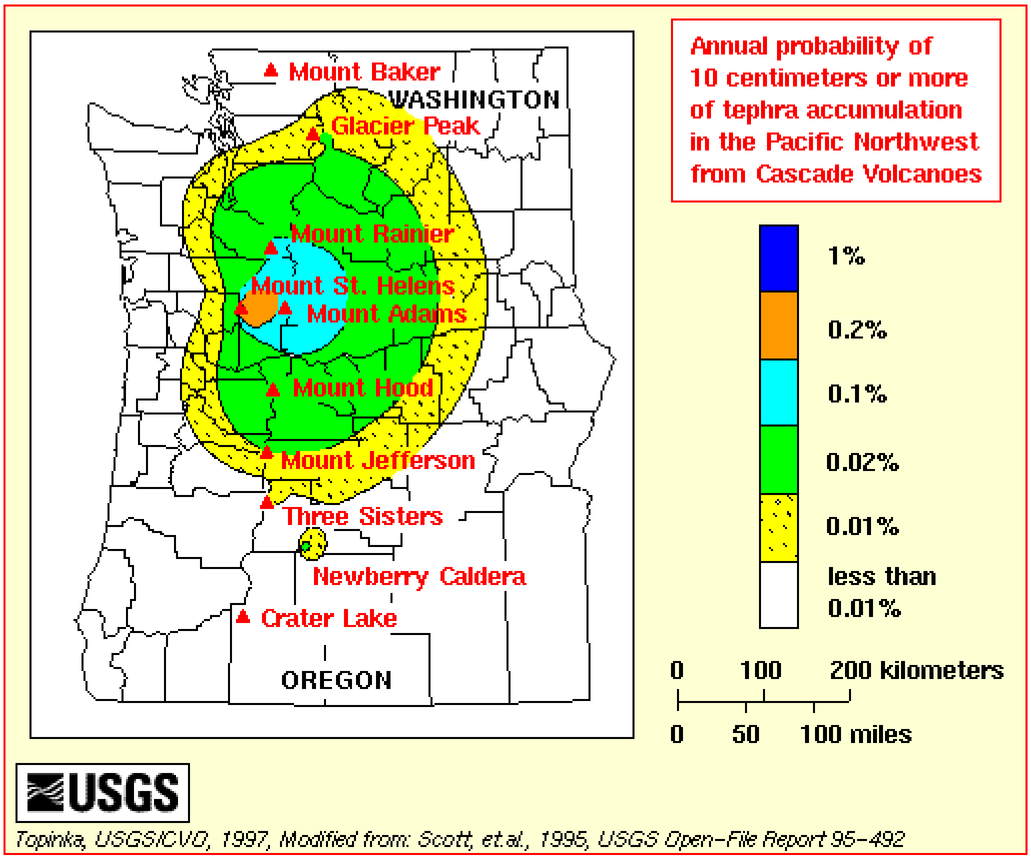
- Lahars originate from landslides of water-saturated debris, from the sudden melting of snow and ice, from heavy rainfall eroding volcanic deposits, or from an outbreak of floodwater from a glacier or from lakes dammed by volcanic eruption. Lahars move faster on the steep slopes nearest their source, attaining speeds up to 40 miles per hour; they can travel more than 50 miles downstream. Close to the volcano, lahars have the strength to rip huge boulders, trees, and buildings from the ground and carry them down valley. Farther downstream, they can entomb everything in their path in mud. Historically, lahars have been one of the most deadly volcanic hazards.[7]

Table 1. Probability of Annual Occurrence of Volcanic Lahars

Volcano	***Lahar***	***Annual Probability***
Glacier Peak	Lower Suiattle River	1-2 in 1,000
	Puget Sound	1-2 in 10,000
	Stillaguamish River	< 1 in 10,000
Mount Adams	Trout Lake	1 in 1,000 to 1 in 10,000
Mount Baker	Case 2 (Debris Flows)	≥1 in 100
	Case 1 (Nooksack River)	≤1 in 500
	Case M (Puget Sound)	1 in 14,000
Mount Rainier	Case III (Debris Flows)	≥1 in 100
	Case II (National Lahar)	1 in 100 to 1 in 500
	Case I (Electron Mudflow)	1 in 500 to 1 in 1,000
	Case M (Osceola Mudflow)	≤ 1 in 10,000
Mount St. Helens	Not calculated due to 1980 eruption	
Mount Hood	Sandy River	1 in 15 to 1 in 30 chance in 30 yrs.
Source: U.S. Geologic Survey volcano hazard reports, 1995 and 1998		

- Tephra falls are from explosive eruptions that blast fragments of rock and ash into the air. Large fragments fall to the ground close to the volcano. Small fragments and ash can travel thousands of miles downwind and rise thousands of feet into the air. In some cases, ash can harm the human respiratory system. Heavy ash fall can create darkness. Ash can clog waterways and machinery, cause electrical short circuits, drift into roadways, railways, and runways. Ash harms mechanical and electronic equipment, and can cause jet engines on aircraft to stall. The weight of ash, particularly when it becomes water saturated, can cause structural collapse, especially when it approaches 10- cm depth and is wet. Ash carried by winds can be a hazard to machinery and transportation systems for months after an eruption.

The most serious tephra hazard in the region is due to Mount St. Helens, the most prolific producer of tephra in the Cascades during the past few thousand years. The map below provides estimates of the annual probability of tephra fall of 10 centimeters (about 4 inches) or greater affecting the region from all volcanoes. Probability zones extend farther east of the range because prevailing winds are from the west most of the time.



- Lava erupted from vents can form lava flows or steep-sided lava domes. Cascade Range lava flows are relatively short, seldom reaching more than 10 miles from the source, and slow moving. The heat of lava flows can melt ice and snow, creating lahars, or start forest or grass fires. They can bury roads and escape routes. Lava domes extruded on steep slopes are subject to collapse, which is one way a pyroclastic flow forms.

- Pyroclastic flows are high-speed avalanches of hot ash, rock fragments, and gas that move down the sides of a volcano during explosive eruptions or when the steep edge of a lava dome breaks apart and collapses. These flows, which can reach 1,500 degrees F and often move up to 100-150 miles per hour, are capable of knocking down and burning everything in their paths. Pyroclastic

> flows from Cascade volcanoes rarely travel more than 5 to 10 miles from vents. A pyroclastic surge, a more energetic and dilute mixture of searing gas and rock fragments, also travels very fast. Pyroclastic surges move easily up and over ridges, while flows tend to follow valleys.[8]

Long-term, a volcanic eruption can affect an area in a number of ways, including clogging rivers and streams on the volcano's flank with sediment from lahars and other eruption debris. Transported sediment can affect watersheds for years and decades by reducing their capacity to carry floodwaters, inhibiting their ability to recover, destabilizing their banks, and filling navigable shipping channels. A recent study shows continued movement of large amounts of sediment through the watersheds below Mount St. Helens 20 years after its 1980 eruption.

Past Hazard Events

May 1980 Eruption of Mount St. Helens

<u>Introduction</u>[9]

Mount St. Helens, in southwestern Washington about 40 miles northeast of Vancouver, is one of five volcanic peaks that dominate the Cascade Range in Washington State.

Some Indians of the Pacific Northwest variously called Mount St. Helens "Louwala-Clough," or "smoking mountain." Local Indians and early settlers in the region witnessed occasional violent outbursts of the volcano. It was intermittently active from 1831 to 1857. Some scientists also suspect that Mount St. Helens was active sporadically during the three decades before 1831, including a major explosive eruption in 1800.

The mountain gave little or no evidence of being a volcanic hazard for more than a century after 1857. Most people saw Mount St. Helens as a serene, beautiful mountain playground teeming with wildlife and available for leisure activities throughout the year.

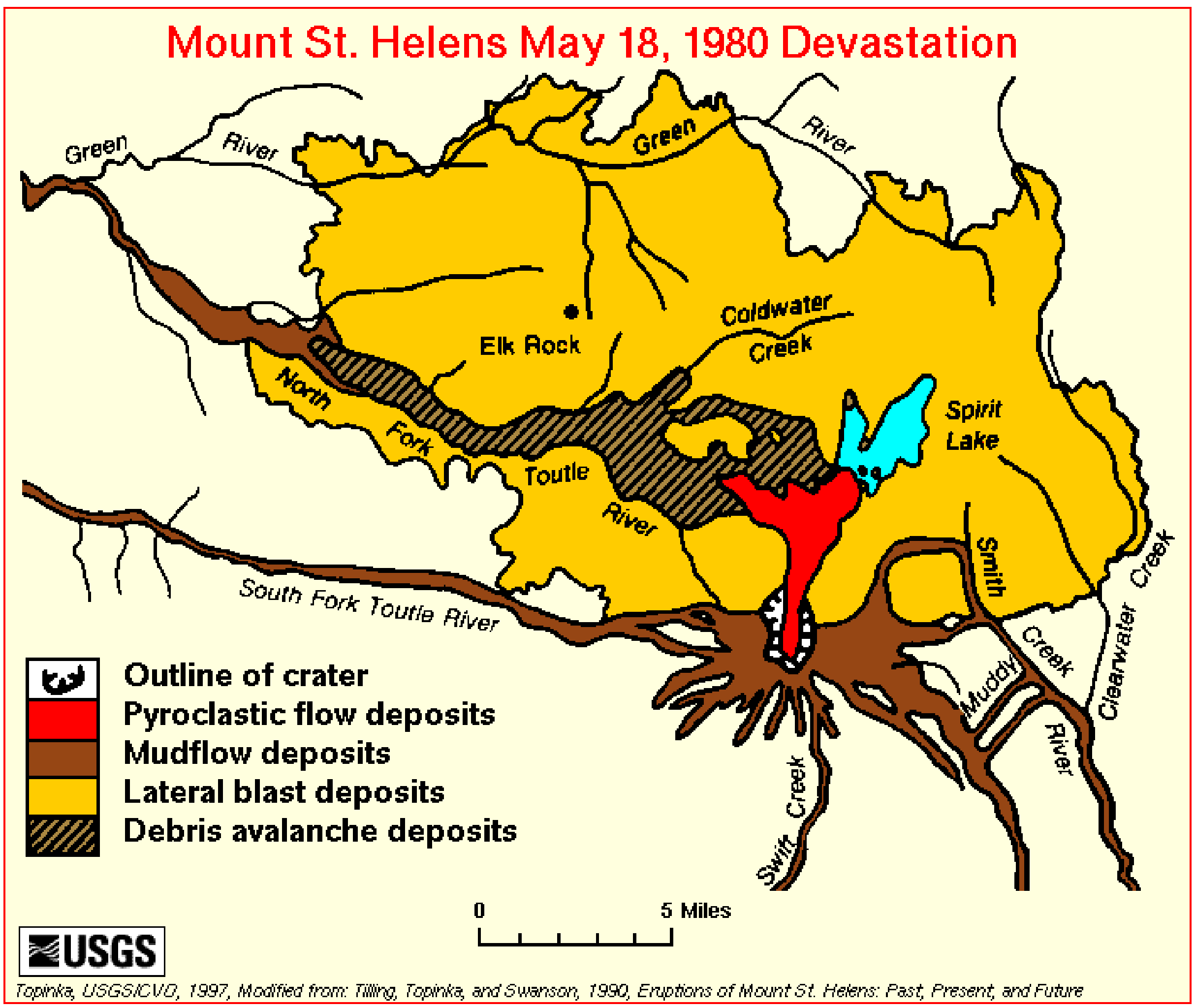
The tranquility of the Mount St. Helens region was shattered in the spring of 1980, however, when the volcano stirred from its long repose, shook, swelled, and exploded back to life.

<u>The volcano awakens and erupts</u>[10]

The first sign of activity at Mount St. Helens was a series of small earthquakes that began on March 16. After hundreds of additional earthquakes, steam explosions on March 27 blasted a crater through the summit ice cap. Within a week, the crater had grown to about 1,300 feet in diameter and two giant crack systems crossed the summit area. By May 17, more than 10,000 earthquakes had shaken the volcano and the north flank had grown outward at least 450 feet to form a noticeable bulge. The deformation was evidence that magma had moved high into the volcano.

On May 18, within 15 to 20 seconds of a magnitude 5.1 earthquake at 8:32 a.m., the volcano's bulge and summit slid away in a huge landslide – the largest on land in recorded history. The landslide depressurized the volcano's magma system, triggering powerful explosions that ripped through the sliding debris. Rocks, ash, volcanic gas, and steam blasted upward and outward to the north. This lateral blast of hot material accelerated to at least 300 miles per hour and slowed as it spread away from the volcano. The blast cloud traveled as far as 17 miles northward from the volcano and the landslide traveled about 14 miles west down the North Fork Toutle River.

The lateral blast produced a column of ash and gas that rose more than 15 miles into the atmosphere in only 15 minutes. Less than an hour later, a second eruption column formed as magma erupted explosively from the new crater. Then, beginning just after noon, swift avalanches of hot ash, pumice, and gas – pyroclastic flows – poured out of the crater at 50 to 80 miles per hour and spread as far as five miles to the north. Based on the eruption rate of these pyroclastic flows, scientists estimate that the eruption reached its peak between 3 and 5 p.m. Over the course of the day, prevailing winds blew 520 million tons of ash eastward across the United States and caused complete



darkness in Spokane, 250 miles from the volcano.

During the first few minutes of this eruption, parts of the blast cloud surged over the newly formed crater rim and down the west, south, and east sides of the volcano. The hot rocks and gas quickly melted some of the snow and ice capping the volcano, creating surges of water that eroded and mixed with loose rock debris to form lahars. Several lahars poured down the volcano into river valleys, ripping trees from their roots and destroying roads and bridges.

The largest and most destructive lahar formed by water and sediment flowing out of the huge landslide deposit through most of the day. The lahar eventually flowed into the Cowlitz River. Its peak stage at Castle Rock, about 50 miles downstream from the volcano, wasn't reached until about midnight, more than fifteen hours after the landslide was emplaced. This timing is significant in that lahar effects, while extremely destructive, are not instantaneous. Downstream communities have time to initiate various mitigation efforts particularly if there are plans already in place for such an event.

Five smaller explosive episodes occurred during the summer and fall of 1980. Each produced eruption columns eight to nine miles high and pyroclastic flows down the volcano's north flank. The episodes in June, August, and October also erupted lava in the crater to form a dome. The June and August domes were destroyed by subsequent explosive episodes.

<u>Impact and Aftermath</u>[11]

The May 18, 1980, eruption was the most destructive in the history of the United States; in hours, it caused loss of life and widespread destruction of valuable property.

The eruption resulted in the loss of 57 lives and scores of injuries.

The lateral blast, debris avalanche, mudflows and flooding caused extensive damage. The eruption destroyed all buildings near Spirit Lake, and destroyed more than 200 homes and cabins and damaged many more in Skamania and Cowlitz Counties, leaving many people homeless.

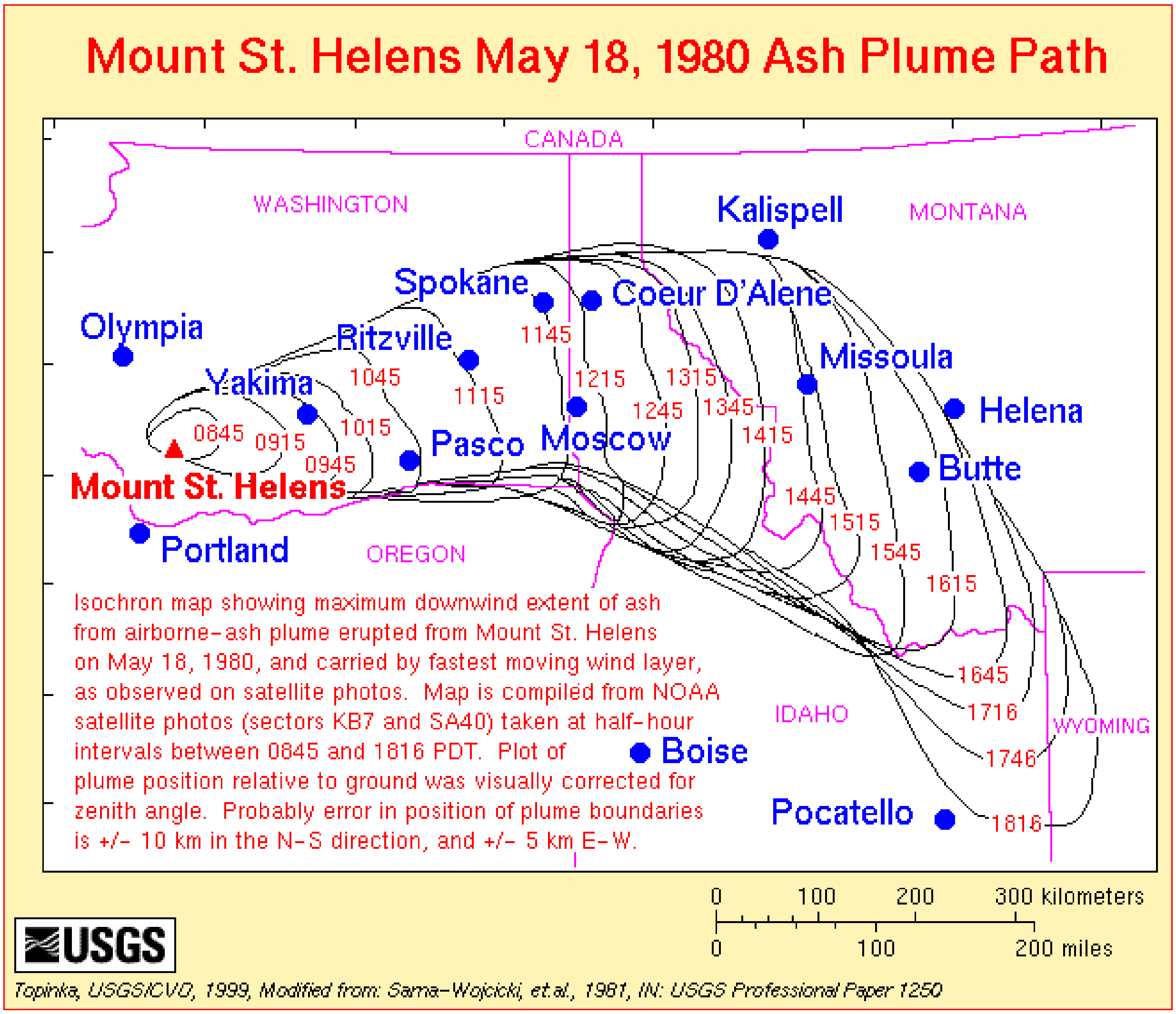
Destroyed or damaged were tens of thousands of acres of prime forest, as well as recreational sites, bridges, roads, and trails, and more than 185 miles of highways and roads and 15 miles of railways.

The lateral blast destroyed or damaged more than 4 billion board feet of salable timber; loggers salvaged about 25 percent of this timber. Wildlife in the Mount St. Helens area suffered heavily.

Thick ash accumulation destroyed crops downwind of the volcano, while crops in areas blanketed by only a thin covering of ash survived. Effects of the ash on the water quality of streams, lakes, and rivers were short lived and minor.

The fine-grained, gritty ash caused substantial problems for internal-combustion engines and other mechanical and electrical equipment. The ash contaminated oil systems, clogged air filters, and scratched moving surfaces. Fine ash caused short circuits in electrical transformers, which caused power blackouts.

The ash fall posed temporary but major problems for transportation and for sewage-disposal and water-treatment systems.



Because of greatly decreased visibility during the ash fall, many highways and roads were closed to traffic, some only for a few hours, but others for weeks. Interstate 90 from Seattle to Spokane closed for a week. Ash accumulation and poor visibility disrupted air transportation for up to two weeks, shutting down several airports in Eastern Washington, and causing the cancellation of more than one thousand commercial flights.

The removal and disposal of ash from highways, roads, buildings, and airport runways posed a monumental task for some Eastern Washington communities. Workers cleared an estimated 2.4 million cubic yards of ash – weighing about 900,000 tons – from highways and airports throughout the state. Ash removal cost $2.2 million and took 10 weeks in Yakima.

The sewage-disposal systems of several municipalities that received a half-inch or more of ash, including Moses Lake and Yakima, were plagued by ash clogging and damage to pumps, filters, and other equipment. Water supply systems using deep wells and closed storage were minimally affected.

The eruption showed that the time it took communities to recover from the ash fall was in proportion to the quantity that fell on them. For example, Yakima, Ritzville, and Spokane all experienced significant disruptions in transportation, business activity and community services for nearly two weeks after the eruption.[12]

Accurate cost figures of the destruction and damage caused by the May 18 eruption are difficult to determine. Early estimates ranged from $2 to $3 billion, primarily reflecting the timber, civil works, and agricultural losses. An International Trade Commission study requested by Congress estimated the loss at $1.1 billion. Congress voted a supplemental appropriation of $951 million for disaster relief, the largest shares of which went to the Small Business Administration, U.S. Army Corps of Engineers, and the Federal Emergency Management Agency.

There were indirect and intangible costs of the eruption as well. Unemployment in the region near Mount St. Helens rose tenfold in the weeks following the eruption, returning to near normal once timber salvaging and ash-cleanup operations were underway. Only a small percentage of residents left the region because of this job loss. Several months after May 18, a few residents reported experiencing stress and emotional problems even though they coped successfully during the crisis. The counties in the region requested funding for mental health programs to assist such people.

The eruption nearly dealt a crippling blow to tourism, an important industry in Washington State. Organizers of several conventions, meetings and social gatherings planned for cities and resorts in areas of Washington and neighboring Oregon not affected by the eruption canceled or postponed them; the negative impact on tourism and conventions proved only temporary. Mount St. Helens, perhaps because of its reawakening, regained its appeal for tourists.

Fall 1980 to Fall 1986 Eruption

Beginning in October 1980, 17 eruptive episodes built a new lava dome that reached 876 feet above the crater floor. Minor explosive activity and lahars accompanied several of these episodes. In addition, hundreds of small explosions or bursts of gas and steam occurred, sending ash up to several miles above the volcano. The larger explosions showered the crater with rocks and occasionally generated small lahars.

Fall 1986 to Fall 2004 Quiet Period[13]

From the fall of 1986 to the fall of 2004, Mount St. Helens returned to a period of relative quiet. Occasional, short-lived seismic swarms that lasted minutes to days interrupted this quiet, as did increases in background seismicity reflecting replenishment of magma deep underground, and minor steam explosions as late as 1991. A new glacier grew in the crater, which wrapped itself around and partly buried the lava dome.

September 2004 – Present, Ongoing Eruption[14]

Mount St. Helens reawakened in September 2004 with a swarm of small, shallow earthquakes in and beneath the 1980-1986 lava dome. Within two days, the level of seismicity prompted scientists to issue a notice of volcanic unrest for the first time since 1986. The accelerated size and frequency of earthquakes and noticeable deformation of the glacier within the crater indicated that magma was rising toward the surface, prompting scientists to issue several types of hazard notifications.

An Oct. 1 explosion lofted steam and ash several thousand feet and hurled rock fragments one-half mile across the western half of the glacier and 1980-1986 lava dome. Three more steam and ash explosions occurred through Oct. 5; only the ash fall of Oct. 5 affected populated areas, with a light dusting of ash extending about 60 miles to the northeast part of Mount Rainier National Park. From Oct. 5 through March 2005, earthquake rates and sizes waxed and waned but never regained the peak levels of Sept. 29 – Oct. 5.

Following the brief series of steam-and-ash explosions, the volcano settled into a quieter phase during which a new lava dome appeared. By early February 2005, the new lava dome grew quickly, reaching nearly 1,400 feet (taller than the Empire State Building) above the level of the 1980 crater floor, and a welt and new lava dome together covered an area equivalent to about 60 city blocks.

<u>Potential Hazards Associated With Eruptive Activity</u>

The current dome-growth eruption has been benign compared to the May 18, 1980, eruption. Between October 2004 and March 2005, however, it produced two notable explosions that lofted ash plumes which drifted hundreds of miles downwind and hurled rock fragments up to 1 foot in diameter up to a mile across the crater. Continued growth and occasional collapse of the new lava dome may produce additional small explosions and avalanches of hot debris that could sweep out from the dome. Both explosions and hot-rock avalanches can create ash clouds which could endanger aircraft and affect people on the ground. Rock avalanches or small explosions that spew hot gases and ash can swiftly melt snow and ice and form floods or lahars that would surge out of the crater; such floods and lahars could endanger people along the upper North Fork Toutle River.

Status of the Eruption and Outlook[15]

From a geologic perspective of the past several thousand years, the current dome-building activity is routine for Mount St. Helens and not out of the ordinary. The volcano is rebuilding itself following the 1980 eruption. For the foreseeable future, dome-building is likely to continue at roughly the same rate as it has for the past several months.

The hazard assessment of the volcano by scientists at the U.S. Geological Survey's Cascades Volcano Observatory is unchanged from the 1995 hazard report. Hazards from the eruption (ash fall, rock fall) likely will be contained to the crater and flanks of the volcano for the foreseeable future; fallout beyond about six miles from the volcano likely will be minimal. However, scientists caution that experience from Mount St. Helens and volcanoes elsewhere show that changes in activity can occur suddenly, sometimes with little or no warning.

Likelihood of Future Hazard Events and Areas Likely to be Impacted

Glacier Peak[16, 17]

Glacier Peak has erupted several times since the Ice Age glaciers retreated 15,000 years ago – most recently around the 18th century. Since glacial times, Glacier Peak has had larger and more explosive eruptions than any Washington volcano except Mount St. Helens. Glacier Peak and Mount St. Helens are distinct from other Washington Cascade volcanoes in their tendency to produce large, explosive eruptions that break erupting lava into small fragments and disperse them high into the atmosphere.

Lahars represent the greatest hazard, followed by tephra fall.

The April 2005 assessment by the U.S. Geological Survey considers Glacier Peak to be the 12th most dangerous volcano in the nation, based on the potential threat it poses to aviation, life, and the built environment.

Lahar:

- Glacier Peak has produced numerous lahars and floods in the past 14,000 years, at least some of which began as pyroclastic flows or surges. Lahars have descended the Suiattle, White Chuck, Sauk, and Skagit River valleys during several eruptive periods. Even the North Fork Stillaguamish River valley, which previously was an outflow route of the Sauk River, has been inundated by Glacier Peak lahars. Two eruptive periods, about 6,000 and 13,000 years ago, repeatedly produced large lahars, some of which reached Puget Sound.

- Collapse of up to one-third of the volcano's structure that lies above 6,000 feet elevation would cause the largest credible lahar. It would reach the Skagit River delta in several hours and cover a significant portion of the Skagit and Sauk floodplains with debris. Below the Sauk-Skagit confluence, the lahar hazard zone covers more than the floodplain. Below the confluence with the Baker River, this hazard zone coincides with the one drawn for lahars from Mount Baker.

- The Stillaguamish River valley potentially could be inundated by a lahar if the river were once again to become a main drainage outflow for Glacier Peak.

- Based on past events, the annual probability for a lahar that extends at least to the lower Suiattle River or to the confluence of the White Chuck and Sauk Rivers is roughly 1 in 1,000 to 1 in 2,000. The annual probability that a lahar would reach Puget Sound is about 1 to 2 in 10,000. The annual probability of lahars inundating the Stillaguamish River valley is thought to be less than 1 in 10,000.

Tephra:

- Eruptions of Glacier Peak have deposited at least nine layers of tephra near the volcano in postglacial time. By far the thickest deposits were east, southeast, and south of the volcano during a series of powerful eruptions about 12,500 to 13,100 years ago. The average frequency of tephra-producing eruptions is roughly one every 2,000 years.

- Due to prevailing winds, tephra is far more likely to fall on the east side of the volcano within a few tens of miles of the summit than on the west side. No buildings lie within this wilderness area. However, any repetition of the huge eastside tephra accumulations of about 13,100 years ago would cause problems at least as far as Chelan County, probably much farther east and likely to communities out of state.

A lateral volcanic blast from Glacier Peak most likely would be smaller than the 1980 Mount St. Helens blast zone. Topography would strongly channel a blast flow toward the northwest or southeast, so that it would reach far out only along valleys – farthest to the northwest.

Ballistic projectiles rarely are thrown more than 3 miles from the mountain; but unlike tephra falls, they can be in directions other than downwind.

Pyroclastic-flow deposits about 12,500 to 13,100 years old fill the floor of White Chuck valley at least as far as 6.5 miles northwest of the summit. Pyroclastic-flow and -surge deposits about 5,500 years old on the east volcano flank lie 5 miles from the summit. It is likely these flows went much farther; erosion and burial has hidden some of the evidence.[18]

Lava flows extend down all flanks from Glacier Peak's summit but nowhere farther than about 6 miles from the summit. Future flows also would be confined to this area.

Because the lava-flow zone lies entirely in wilderness, hazards to developed areas from lava flows are negligible, though secondary effects such as forest fires could reach developed areas.

In future eruptions, lava flows and ballistic projectiles probably will be contained within 5 to 6 miles of the summit. Pyroclastic flows could travel 13 miles to the west and north of the summit, while pyroclastic surges could travel another three miles farther.

Mount Adams[19, 20]

Mount Adams dominates a volcanic field in Skamania, Yakima, Klickitat, and Lewis counties of south-central Washington. The volcano has erupted little during the past 10,000 years; it is less active than neighboring Mounts St. Helens, Rainier, and Hood. Highly explosive eruptions of Mount Adams have been rare. Much of the hazard area for eruptive events lies in the Gifford Pinchot National Forest or remote areas of the Yakama Indian Reservation. Areas of greatest concern are located along the channels and floodplains of rivers subject to lahars.

The April 2005 assessment by the U.S. Geological Survey considers Mount Adams to be the 19th most dangerous volcano in the nation, based on the potential threat it poses to aviation, life, and the built environment.

Lahars:

- Streams that drain the north and northwest flanks of Mount Adams can discharge sediment from lahars into Swift Reservoir on the Lewis River and Riffe Lake on the Cowlitz River. Streams that drain the southwest and east flanks can deliver sediment to the Columbia River and could affect navigation and hydroelectric operations at Bonneville Dam. Impacts on the small reservoir and hydroelectric operation on the White Salmon River could be severe.

- The Trout Lake avalanche and lahar, which occurred in the upper White Salmon River drainage about 6,000 years ago, is the only debris avalanche or lahar that has traveled far (about 35 miles) beyond the volcano flanks in the past 10,000 years. However, several smaller lahars have reached the Trout Lake lowland.

- A large avalanche-triggered lahar in the White Salmon drainage could bury the Trout Lake lowland, enter the Columbia River, and inundate both the Oregon and Washington shorelines for a considerable distance. A lahar comprising 1 cubic kilometer of debris likely would transport enough sediment to the Columbia to exceed the capacity of usable storage of Bonneville Reservoir and cause overtopping of Bonneville Dam. Consequences of dam overtopping, which might trigger dam failure, could be severe. A large lahar could itself dam the Columbia River, back up water behind it, and fail, with similarly severe results.

- A large lahar in the Klickitat valley could affect the Columbia River, Bonneville Reservoir, and Bonneville Dam in a manner similar to that of a large lahar in the White Salmon valley.

- Lahars large enough to reach the Trout Lake lowland have annual probabilities of about 1 in 100 to 1 in 1,000. A lahar the size of the Trout Lake lahar has an annual probability of about 1 in 1,000 to 1 in 10,000, whereas a lahar of sufficient magnitude to inundate the entire length of one or more valleys has not occurred in the last 10,000 years and has an annual probability less than 1 in 10,000.

- Small avalanches or lahars triggered by rainfall, rapid snowmelt, heavy snowfall, or glacier outbursts occur frequently, but seldom travel more than a few miles from their sources on steep volcano flanks. Such events have annual probabilities greater than 1 in 10; they endanger backcountry recreationists and may damage timber, trails and bridges, but not settled areas.

- A number of lakes close to the volcano in the Lewis River and Cowlitz River valleys could play a role in the size of future lahars. Both Swift Reservoir and Riffe Reservoir generally are not at risk from lahar. This assumes, however, that operators of the reservoirs' dams would lower lake levels in advance of an imminent eruption – as they did for the May 1980 eruption of Mount St. Helens – and that a lahar reaching the reservoir would not be appreciably larger than those of 1980.[21]

The dominant type of eruption at Mount Adams, as well as in the adjacent volcanic fields, produces lava flows, or streams of molten rock. Several significant lava flows have occurred in the region during the past 10,000 years, most traveled between 8 and 20 miles.

Tephra from Mount Adams does not pose a serious or widespread hazard; eruptions have blanketed only areas within a few miles from the volcano with ash fall of several inches. Thinner deposits probably extended tens of miles father. Pyroclastic flows have been rarer at Mount Adams during the past 10,000 years than at other nearby volcanoes.

The probability of a lava flow occurring in a year on Mount Adams itself is about 1 in 1,000; the probability of a larger lava flow that significantly affects a given point in the region surrounding the volcano occurring in a year is about 1 in 30,000 to 1 in 1,000,000, depending on size and location of the flow.

The maximum credible eruption at Mount Adams is an event of very low annual probability, less than 1 in 100,000.

Mount Baker[22, 23]

Mount Baker is not showing signs of renewed activity, but will again; its main hazards are lahars and debris avalanches. These may occur without an accompanying eruption.

The April 2005 assessment by the U.S. Geological Survey considers Mount Baker to be the 11th most dangerous volcano in the nation, based on the potential threat it poses to aviation, life, and the built environment.

Lahars:

- The largest lahar, about 6,800 years ago, probably originated as a large debris avalanche. This flow moved down the Middle Fork of the Nooksack River to the mainstem Nooksack River; it can be traced as far downstream as Deming, where younger river deposits have buried it. In all likelihood, this lahar traveled all the way to Puget Sound.

  This lahar is a Case M lahar; it has a recurrence interval of about once every 14,000 years.

- Of special concern is a lahar or pyroclastic flow entering Baker Lake, southeast of the mountain, displacing enough water to overtop Upper Baker Dam or cause failure of the dam. Either scenario would have consequences for the stability of the dam. If the dam fails, the resulting lahar or flood most likely would affect the entire Skagit River floodplain to Puget Sound. Such a lahar could inundate this zone to a depth of up to 16 feet.

- A very large lahar, or a series of lahars moving down the Nooksack River, similar to the one that occurred 6,800 years ago, could deposit enough material in the stretch of river between Lynden and Everson to raise the river bed enough to cause flood waters to spill into the Sumas River or to divert the Nooksack River into the Sumas River basin which would result in serious to severe impacts within the Province of British Columbia as well as to the city of Sumas, WA.

- A Case 1 lahar is a non-cohesive debris flow resulting from melting snow and ice from eruptive activity, increased fumarolic heating or steam explosions. This is the most likely event to affect drainages on the north side of the volcano. Such a debris flow affecting the Nooksack River drainage has a projected recurrence rate of about once every 500 years.

- A Case 2 lahar, about the same size as a 100-year flood, comprises cohesive debris flows from small to moderate debris avalanches from either Sherman Crater or the upper Avalanche Gorge. Such lahars could occur during times of no volcanic activity. Recurrence rate for a case 2 lahar is about once every 100 years. Increased volcanic activity could increase the recurrence intervals for both Case 1 and Case 2 lahars, which is a concern for each volcano.

Only one episode of pyroclastic-flow and -surge activity is recognized. It took place about 9,600 years ago, with deposits confined to the Boulder Creek valley, southeast of the mountain.

No lateral blast of the magnitude of the 1980 Mount St. Helens event has been recognized at Mount Baker. Such an event is credible, although unlikely. A blast of similar magnitude could threaten the communities of Glacier, Van Zandt, Concrete, and perhaps Deming.

Mount Baker has not produced large amounts of tephra in the past and probably will not in the future. Because winds are dominantly from the west, it is likely that any tephra will be carried to the east away from major communities. The annual likelihood of one centimeter or more of tephra falling in eastern Whatcom County, western Okanogan County, and parts of Skagit and Chelan Counties and southern British Columbia from an eruption of Mt. Baker is one chance in 50,000.

Mount Rainier[24, 25, 26, 27]

Mount Rainier – at 14,410 feet the highest peak in the Cascade Range – has more glacial ice than the rest of the Cascade volcanoes combined. This tremendous mass of rock and ice, in combination with great topographic relief, poses a variety of geologic hazards. Most geologic phenomena affect only the immediate vicinity of Mount Rainier; however, lahars and tephra falls could affect great numbers of people far from the volcano. Symptoms of volcanic unrest would greatly increase the probability of debris avalanches, especially those of large size that might affect populated areas of the Puget Sound lowland.

The April 2005 assessment by the U.S. Geological Survey considers Mount Rainier to be the third most dangerous volcano in the nation, based on the potential threat it poses to aviation, life, and the built environment.

Lahars:

- During the past 10,000 years, at least 60 lahars have moved down valleys that begin on Mount Rainier. Lahars are the greatest threat to communities below the volcano. More than 150,000 people live on deposits of old lahars. Lahars that reached the Puget Sound lowland have occurred about every 500 to 1,000 years, with smaller flows not traveling as far as the lowland occurring more frequently. Scientists believe there is a one in seven chance that a lahar will reach the Puget Sound lowland in the average human lifespan if future lahars occur at rates similar to those of previous lahars.

- Past lahars at Mount Rainier have varied tremendously in size and frequency. For purposes of hazards assessment, there are four classes of lahar. In order of decreasing size and increasing frequency, they are Case M, Case I, Case II, and Case III lahars.

- Case M lahar: The largest lahar to occur in the past 10,000 years is the Osceola Mudflow. It is at least 10 times larger than any other known lahar from Mount Rainier, and is one of the largest known volcanic mudflows in the world.[28] It formed about 5,600 years ago when a massive debris avalanche of weak, chemically altered rock transformed into a lahar. Osceola deposits cover an area of about 212 square miles in the Puget Sound lowland, extending at least as far as Kent and to Commencement Bay in Tacoma. The communities of Orting, Buckley, Sumner, Puyallup, Enumclaw, and Auburn are wholly or partly located on top of Osceola Mudflow deposits, which range from a few feet to 200 feet thick.

  A Case M lahar entering Riffe Lake on the Cowlitz River could affect areas downstream in one of two ways:
  1. The lake might contain the lahar if the level of the lake behind the dam is lowered and the lahar was small.
  2. The lahar could cause the dam to fail or catastrophically displace a significant volume of water to inundate the Cowlitz River valley all the way to the Columbia River at Longview and Kelso.

  Geologists believe flows of this magnitude occur far less frequently than once every 1,000 years.

- Case I lahar: These flows, generated by debris avalanches much smaller than the Osceola Mudflow, have occurred on average about once every 500 to 1,000 years during the past 5,600 years. Most Case I flows have reached some part of the Puget Sound lowland. The Electron Mudflow reached the lowland about 500 years ago along the Puyallup River. Its deposits at Orting are as much as 18 feet thick and contain remnants of an old-growth forest.

  A Case I lahar occurring today could destroy all or parts of Orting, Sumner, Puyallup, Fife, the Port of Tacoma, and possibly Auburn. Also, a Case I lahar entering Alder Lake on the Nisqually River could affect areas downstream in one of two ways:
  1. The lake might contain the lahar if the level of the lake behind the dam is lowered and the lahar was small.
  2. The lahar could cause the dam to fail or catastrophically displace a significant volume of water to inundate the downstream Nisqually River valley all the way to Puget Sound near Olympia.

- Case II lahar: These flows, caused by eruptions swiftly melting snow and ice, have an average recurrence interval near the lower end of the 100- to 500-year range. More than a dozen lahars of this type have occurred in the past 6,000 years. A few have reached the Puget Sound lowland, including the National Lahar, which occurred about 2,000 years ago. It inundated the Nisqually River valley to depths of 30 to 120 feet and flowed all the way to Puget Sound. About 1,200 years ago, another lahar filled valleys of both forks of the White River to depths of 60 to 90 feet, and flowed 60 miles to Auburn.

The lower Green and Duwamish River valley could be at significant risk to a Case II lahar or redistribution of new lahar deposits if one of two conditions occurs:

1. The available storage of Mud Mountain Reservoir is reduced significantly by a lahar or post-lahar sedimentation.
2. The profile of the lower White River valley south of Auburn is changed sufficiently by a lahar or post-lahar sedimentation to cause the White and Puyallup Rivers to drain northward into the Green and Duwamish River valley.

- Case III lahar (now called a debris flow): These flows are relatively small but occur frequently, every one to 100 years. This class of flows includes small debris avalanches as well as debris flows triggered by sudden, unpredictable release of water stored by glaciers. These debris flows are largely restricted to the slopes of the volcano, rarely moving beyond the National Park boundary; since 1926, outburst floods destroyed or damaged bridges, roads, and national park visitor facilities on about 10 occasions. Glacial outburst floods are unrelated to volcanic activity and typically coincide with periods of unusually high temperatures or unusually heavy rain in summer or early autumn. About three dozen such flows occurred during the 20th century.

Lahar Warning System: Because of the higher level of risk from lahars in the Carbon and Puyallup River valleys, the U.S. Geological Survey and Pierce County in the mid 1990s installed lahar detection and warning systems in the valleys just outside the national park. The system consists of arrays of five acoustic flow monitors along each river that detect the ground vibrations caused by a lahar. Computerized evaluation of data confirms the presence of a flowing lahar and issues an automatic alert to Pierce County and state emergency management agencies; emergency managers then can initiate response measures such as evacuations. This system reduces, but does not eliminate, risk in the lahar pathways.

The U.S. Geological Survey has estimated travel times for lahars up to 100 million cubic meters, similar in size to a Case I lahar, for both the Puyallup and Carbon River basins (see page 18 for an example of a Case I lahar).

Puyallup River lahar – A lahar originating in the Sunset Amphitheater at the top of the Puyallup Glacier is projected to reach the following communities in the estimated times after the lahar warning system sounds an alarm:

Community	Distance from the Source	Estimated Arrival After Alarm
Orting	32 miles	42 minutes
Sumner	40 miles	65 minutes
Puyallup	43 miles	78 minutes
Auburn	46 miles	96 minutes
Commencement Bay, Tacoma	49 miles	108 minutes

Carbon River lahar – A lahar originating near the middle or upper part of Willis Wall at the top of the Carbon Glacier is projected to reach the following communities in the estimated times after the lahar warning system sounds an alarm:

Community	Distance from the Source	Estimated Arrival After Alarm
Carbonado	24 miles	12 minutes
Wilkeson	27 miles	18 minutes
Orting	32 miles	42 minutes

Larger lahars would reach downstream communities more quickly.

Other hazards:

Tephra: Mount Rainier is a moderate tephra producer relative to other Cascade volcanoes. Eleven eruptions have deposited layers of tephra near the volcano in the past 10,000 years; the average interval between eruptions is about 900 years. Tephra loads of 4 inches or more are most likely to occur east of the mountain, within a few tens of miles of the summit.

Pyroclastic flows: Lack of evidence of pyroclastic flows leads scientists to conclude that most convert to lahars as they pass over snow and ice. Two pyroclastic flows in the past 2,500 years traveled only about seven miles from the volcano.

Ballistic projectiles: They rarely travel three miles from the vent; most projectiles are less than three feet across. The chief hazard from ballistic projectiles is direct impact. Projectiles may still be quite hot when they land, and can start fires if they land near combustible materials.

In future eruptions, pyroclastic flows and surges, as well as lava flows and ballistic projectiles, probably will not extend beyond the national park boundaries.

Lava flows: Much of Mount Rainier is composed of lava flows. The most serious hazard of lava flows is when they contact snow and ice, creating floods and lahars. The only lava flows known from Mount Rainier in the past 10,000 years are those that built the summit cone, constructed within the past 5,600 years.

The annual probability of pyroclastic flows, surges, lava flows, and ballistic projectiles affecting some part of the area is less than 1 percent.

Lateral blast: At least one laterally directed explosion accompanied the debris avalanche that produced the Osceola Mudflow, as the mountain's hydrothermal system was depressurized. Three factors conducive to such an event – substantial volumes of weak hydrothermally altered rock, substantial topographic relief, and an active hydrothermal system – are present at Mount Rainier.

The Mount Rainier blast-hazard zone extends farthest to the northwest of the volcano because of the lack of high ridges or other topographic barriers in that direction.

Mount St. Helens[29, 30]

Mount St. Helens remains an active and dangerous volcano. In the last 515 years, it produced four major explosive eruptions and dozens of lesser eruptions. One of those, in 1480, was about five times larger than the May 18, 1980 eruption; even larger eruptions have occurred during Mount St. Helens' lifetime.

Lahars are a greater threat to life and property in communities of the Cowlitz and lower Toutle River drainages than any other volcanic phenomenon. Previous lahars, including those from the May 18, 1980 eruption, traveled 30 to 60 miles, often reaching the Columbia River via the Toutle, Kalama or Lewis Rivers. Non-eruption events such as intense storm runoff over erodible sediment, landslides, or failure of the Castle Lake impoundment can generate lahars. Neither a large debris avalanche nor a major lateral blast like those of May 1980 is likely now that a deep, open crater has formed.

- The amount of available water limits the maximum size of a potential lahar. Rapid melting of snow and ice in the crater or a sudden outbreak of Castle Lake are the most likely mechanisms to cause a lahar. Either would produce a lahar only in the North Fork Toutle River and downstream. A sufficient volume of permanent and seasonal snow and ice exists in winter or spring on the outer flanks of the volcano to produce lahars similar in magnitude to those of May 18, 1980, if another large eruption were to occur.

- A number of hydropower reservoirs close to the volcano in the Lewis River valley could play a role in the size of future lahars. The Swift Reservoir and downstream lakes are capable of trapping a lahar and stopping its advance, assuming that operators of the dams would lower pool levels in advance of an imminent eruption – as they did in 1980 – and that a lahar reaching the reservoir would not be appreciably larger than those of May 1980.

- The natural dam at Castle Lake could produce a lahar on its own if the blockage were to fail. Overtopping and possible breaching of the Sediment Retention Structure downstream also could result in a significantly larger lahar in the Toutle and Cowlitz Rivers than postulated.

- The Cowlitz River channel at both Kelso and Longview should contain a lahar similar in size to a 100-year flood, but parts of the Toutle River valley between the Sediment Retention Structure and the Cowlitz River could not contain such a lahar.

- Based on the behavior of lahars from the May 1980 eruption, estimated travel times have been developed for lahars traveling down the North Fork Toutle River valley, and the South Fork Toutle River, Pine Creek, Muddy River, and Kalama River valleys:

Distance from Mount St. Helens	Projected Lahar Travel Time	
	N. Fork Toutle River	S. Fork Toutle River Pine Creek Muddy River Kalama River
20 Kilometers (12.4 miles)	37 minutes	30 minutes
40 kilometers (24.9 miles)	1hour, 8 minutes	1 hour, 21 minutes
60 kilometers (37.3 miles)	3 hours, 27 minutes	2 hours, 20 minutes
80 kilometers (49.7 miles)	4 hours, 43 minutes	3 hours, 31 minutes
100 kilometers (62.1 miles)	8 hours, 50 minutes	5 hours, 12 minutes

Projected recurrence rates for lahars are not available for Mount St. Helens.

Mount St. Helens repeatedly has produced voluminous tephra. While tephra from the May 18, 1980 eruption covered about 22,000 square miles, the lethal impact from falling tephra is likely only in the immediate vicinity of Mount St. Helens; damaging impacts from falling tephra, as described earlier in this profile (see pages 8-10) were seen hundreds of miles away. A larger eruption could cover as much as 40,000 square miles with tephra. Westerly winds prevail, making significant tephra accumulation from a single eruption more likely east of Mount St. Helens.

The calculated annual probability that four or more inches of tephra from a large eruption will fall as far as 40 miles directly east of Mount St. Helens is about 1 in 500. The calculated annual probability that such an eruption would deposit four or more inches 40 miles directly west of Mount St. Helens is less, between 1 and 2 in 10,000.

Lateral blasts may generate complex pyroclastic flows and surges and launch ballistic projectiles. The current shape of the volcano – with its large crater and much lower summit – makes a landslide and massive laterally directed blast similar in size to the May 18, 1980 blast unlikely.

Pyroclastic flows from the May 18, 1980 eruption ran about five miles from the vent. As they impinged on Johnston Ridge, they were deflected westward down valley and eastward to Spirit Lake. During the past 4,000 years in which the volcano's modern edifice formed, numerous pyroclastic flows traveled at least six to nine miles, and at least one older flow traveled up to 12 miles. Although the present crater geometry favors distribution of pyroclastic flows into the North Fork Toutle River valley, all flanks of the volcano are subject to pyroclastic-flow hazard during a large eruption.

Because they are less dense, pyroclastic surges are less constrained by topography than are pyroclastic flows. On May 18, 1980, pyroclastic surges surmounted Johnston Ridge and entered the drainage of South Coldwater Creek, even though the steep north-facing escarpment of the ridge deflected the related pyroclastic flows.

Blasts have launched projectiles from the volcano. A blast related to emplacement of the Sugarbowl dome on the north flank of Mount St. Helens about 1,200 years ago propelled ballistic fragments as large as 2 inches as far as six miles from the vent. More recently, a series of relatively small steam-driven explosions in 1989–91 threw hundreds of blocks, some as large as a yard, for distances of one-half mile from the dome within the Mount St. Helens crater. Similar explosions could occur without warning in the future.

Numerous lava flows have issued from Mount St. Helens. A lava flow from a vent in the present crater would be directed down the north flank of Mount St. Helens and possibly into the upper part of the North Fork Toutle River valley. Most have affected only areas within six miles of the summit, but two basalt flows that issued about 1,700 years ago extended about 10 miles from the volcano's summit; one of them, which flowed south to the Lewis River valley east of Cougar, contains the Ape Cave lava tube.

Note: The above hazard information came primarily from *Volcanic-Hazard Zonation for Mount St. Helens, Washington, 1995*, U.S. Geological Survey, Open-File Report 95-497. Scientists from the Cascades Volcano Observatory reaffirmed the validity of the 1995 hazard report since the volcano's current eruption began in September 2004, saying nothing the volcano has done changes their earlier assessment.

Mount Hood, Oregon[31, 32]

The April 2005 assessment by the U.S. Geological Survey considers Mount Hood to be the fourth most dangerous volcano in the nation, based on the potential threat it poses to aviation, life, and the built environment.

Areas of Clark, Skamania and Klickitat Counties are at risk to the impacts of lahars generated by Mount Hood.

Growth and collapse of lava domes dominated eruptive activity at Mount Hood during the past 30,000 years. The last two episodes occurred 200 and 1,500 years ago. Repeated collapse of lava domes near the site of Crater Rock, Mount Hood's youngest lava dome, generated pyroclastic flows and lahars and built much of the broad smooth fan on the south and southwest flank of the volcano.

After the last eruptive period, sediment choked the Sandy River, enlarged its delta, and pushed the Columbia River against the Washington shore in the Camas-Washougal area.

More than 100,000 years ago, a much larger debris avalanche and related lahar flowed down the Hood River, crossed the Columbia River, and flowed several kilometers up the White Salmon River in Klickitat County. Scientists believe this deposit temporarily dammed the Columbia River.

A future eruption could greatly affect the Columbia River, its shipping channel, and, potentially, hydroelectric installations such as Bonneville Dam, tens of miles from the volcano.

Future lahars and eruption-induced sedimentation are likely to build the Sandy River delta farther out into the Columbia River and narrow the existing channel, which could lead to progressive bank erosion and inundation of land in the Camas-Washougal area of Clark County. The 30-year probability that lahars will inundate areas of the Sandy River valley is about 1 in 15 to 1 in 30. It is impossible to develop a more specific forecast other than to note that areas close to the rivers and land composed of erodible deposits are the most vulnerable.

Future lahars in the Hood River Valley are less probable than in the Sandy River valley, but lahars entering the Columbia from Hood River could push the Columbia against its north bank and cause bank erosion or inundation in Klickitat and Skamania Counties.

Mount Hood is a relatively modest tephra producer, and much of the tephra fall would occur east of the mountain due to prevailing winds.

Jurisdictions Most Threatened and Vulnerable to Volcanic Hazards

The jurisdictions most vulnerable to lava flow, lahars, and ash fall from volcanic eruptions come from U.S. Geological Survey hazard reports and hazard zone maps published for each volcano. Jurisdictions at-risk to lava flow and lahar are those identified on hazard zone maps on the following pages. Jurisdictions at-risk to ash fall are those with a 1 in 1,000 chance of receiving 10 centimeters (4 inches) of ash fall each year on the map on page 5.

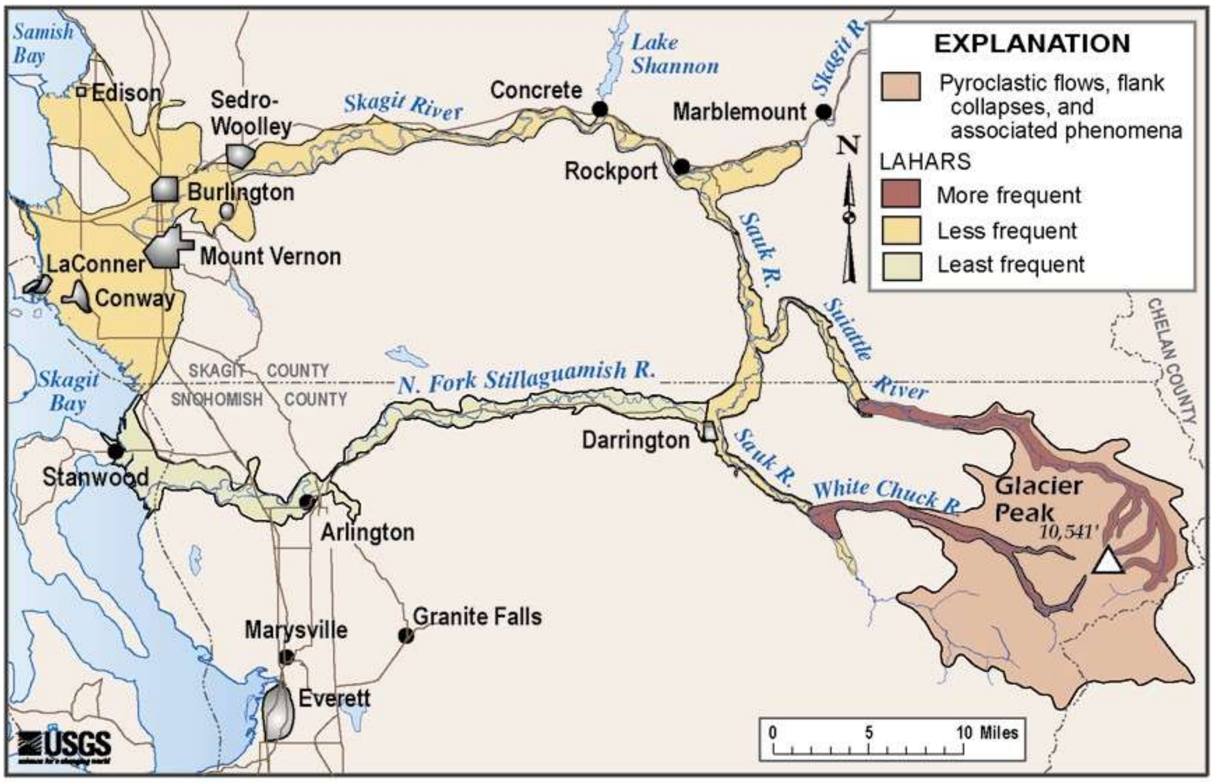
Jurisdictions most vulnerable to the above volcanic hazards are listed below.

Clark (lahar)	Cowlitz (lahar)	King (lahar)	Kittitas (ash)
Klickitat (ash, lahar)	Lewis (ash, lahar)	Pierce (lahar)	Skagit (lahar)
Skamania (ash, lahar)	Snohomish (lahar)	Thurston (lahar)	Whatcom (lahar)
Yakima (ash, lahar)	Chelan (ash)		


Counties Vulnerable to Lahar and Ash Fall
MountBaker
WHATCOM
SANJUAN
PEND OREILLE
SKAGIT
OKANOGAN
FERRY
STEVENS
ISLAND
GlacierPeak
CLALLAM
SNOHOMISH
CHELAN
KITSAP
JEFFERSON
DOUGLAS
SPOKANE
LINCOLN
KING
MASON
GRAYS HARBOR
GRANT
KITTITAS
PIERCE
MountRainier
ADAMS
THURSTON
WHITMAN
PACIFIC
LEWIS
FRANKLIN
GARFIELD
YAKIMA
MountSt.Helens
WAHKIAKUM
MountAdams
COLUMBIA
BENTON
WALLA WALLA
ASOTIN
COWLITZ
SKAMANIA
KLICKITAT
CLARK
Counties Vulnerable to Lahar and Ash Fall
Volcanoes
MountHood,OR

Glacier Peak

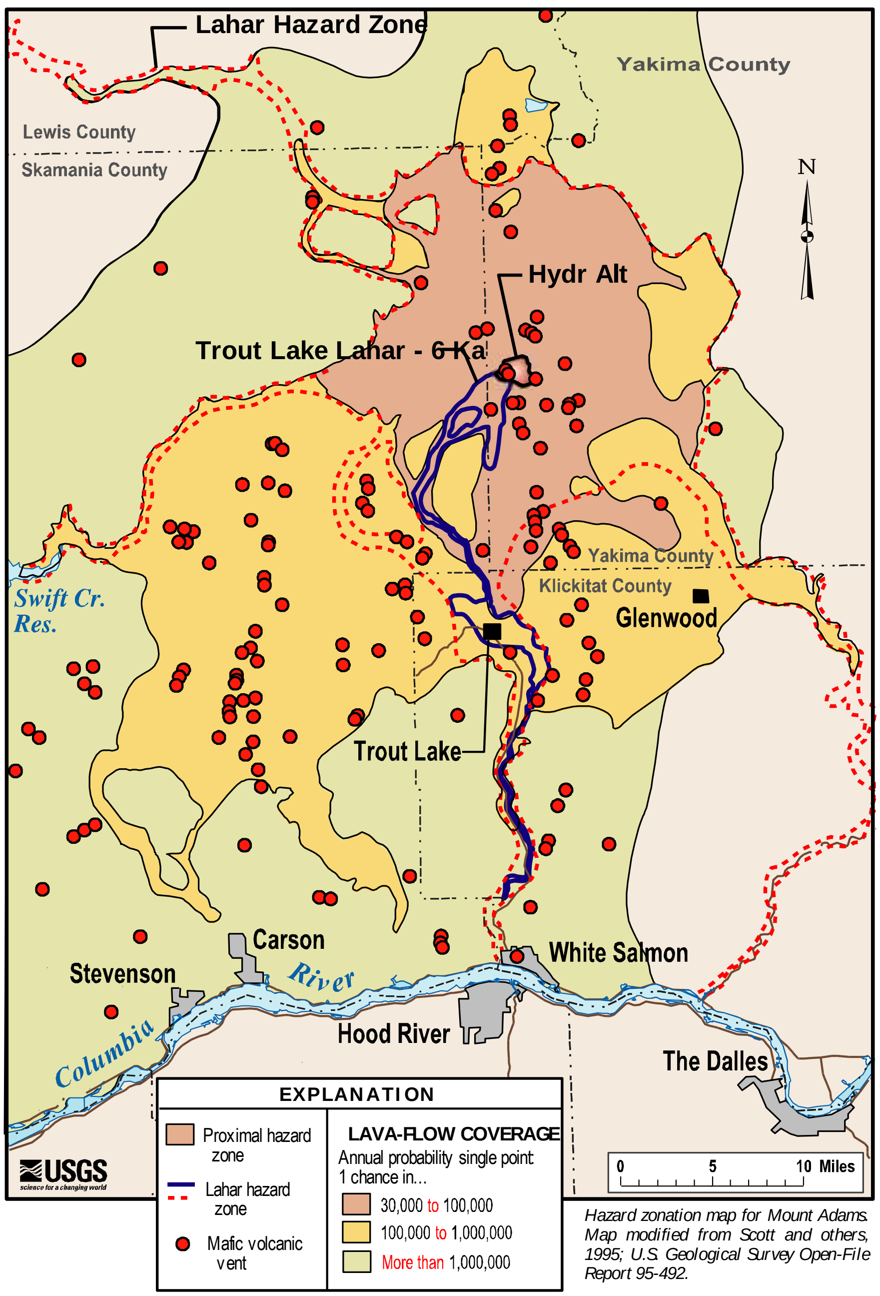
- Skagit County – Burlington, Concrete, Conway, Edison, Hamilton, La Conner, Mount Vernon, Rockport, and Sedro Woolley, plus valleys of the Suiattle, Sauk, and Skagit Rivers.
- Snohomish County – Arlington, Darrington, and Stanwood, plus valleys of the White Chuck, Sauk, and North Fork Stillaguamish Rivers.



Areas at risk from lahars, lava domes, pyroclastic flows, and associated phenomena from Glacier Peak . Map modified from R.B. Waitt and others, U.S. Geological Survey Open-File Report 95-499.

Mount Adams

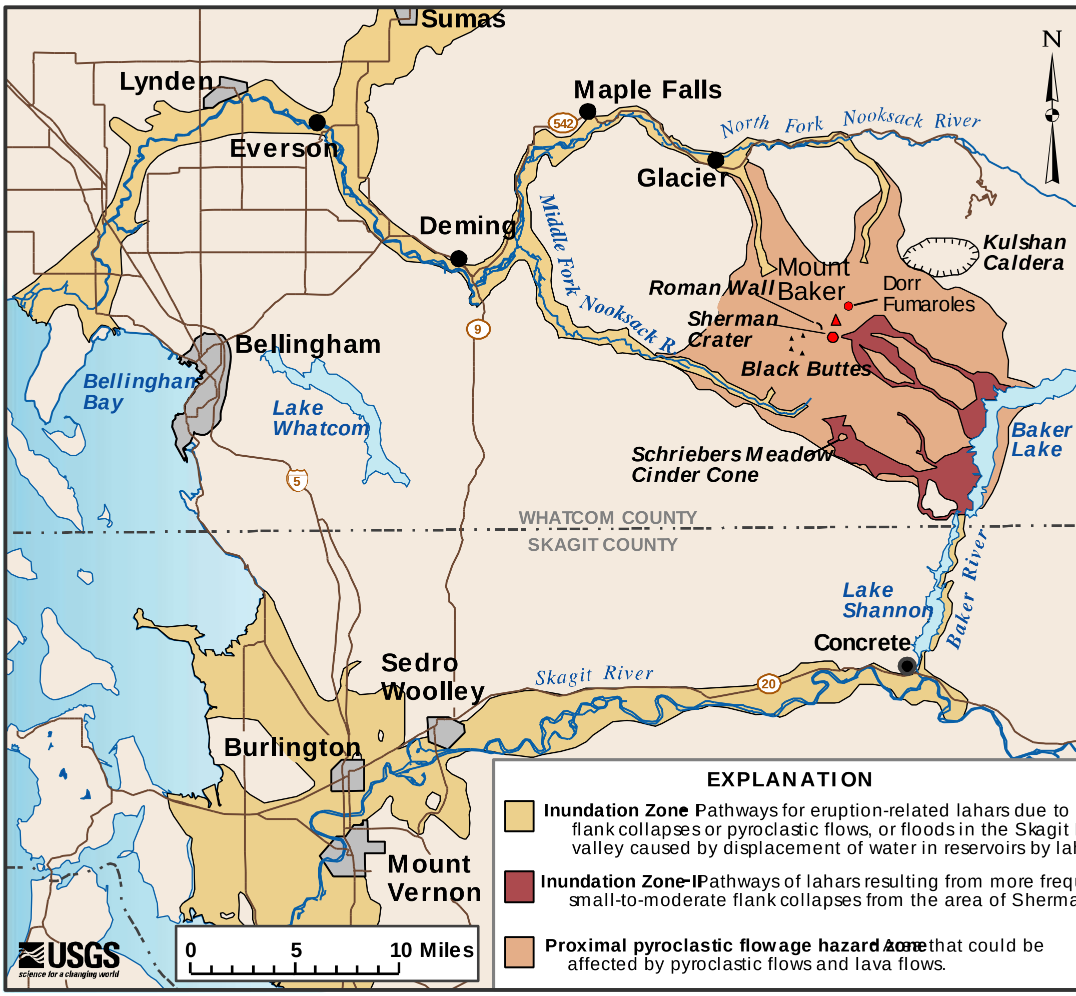
- Klickitat County – Lyle, Trout Lake and the lower White Salmon River valley.
- Skamania County – Carson, Stevenson, and unincorporated areas in the eastern part of the county including valleys of the Cispus and Lewis Rivers.
  - Numerous communities along the Columbia River in both Klickitat and Skamania Counties lie in the local proximal hazard zone for lava flow.
- Lewis County – Unincorporated areas of the Cispus River valley, including Riffe Lake.
- Yakama Nation and Yakima County.



Hazard zonation map for Mount Adams. Map modified from Scott and others, 1995; U.S. Geological Survey Open-File Report 95-492.

Mount Baker

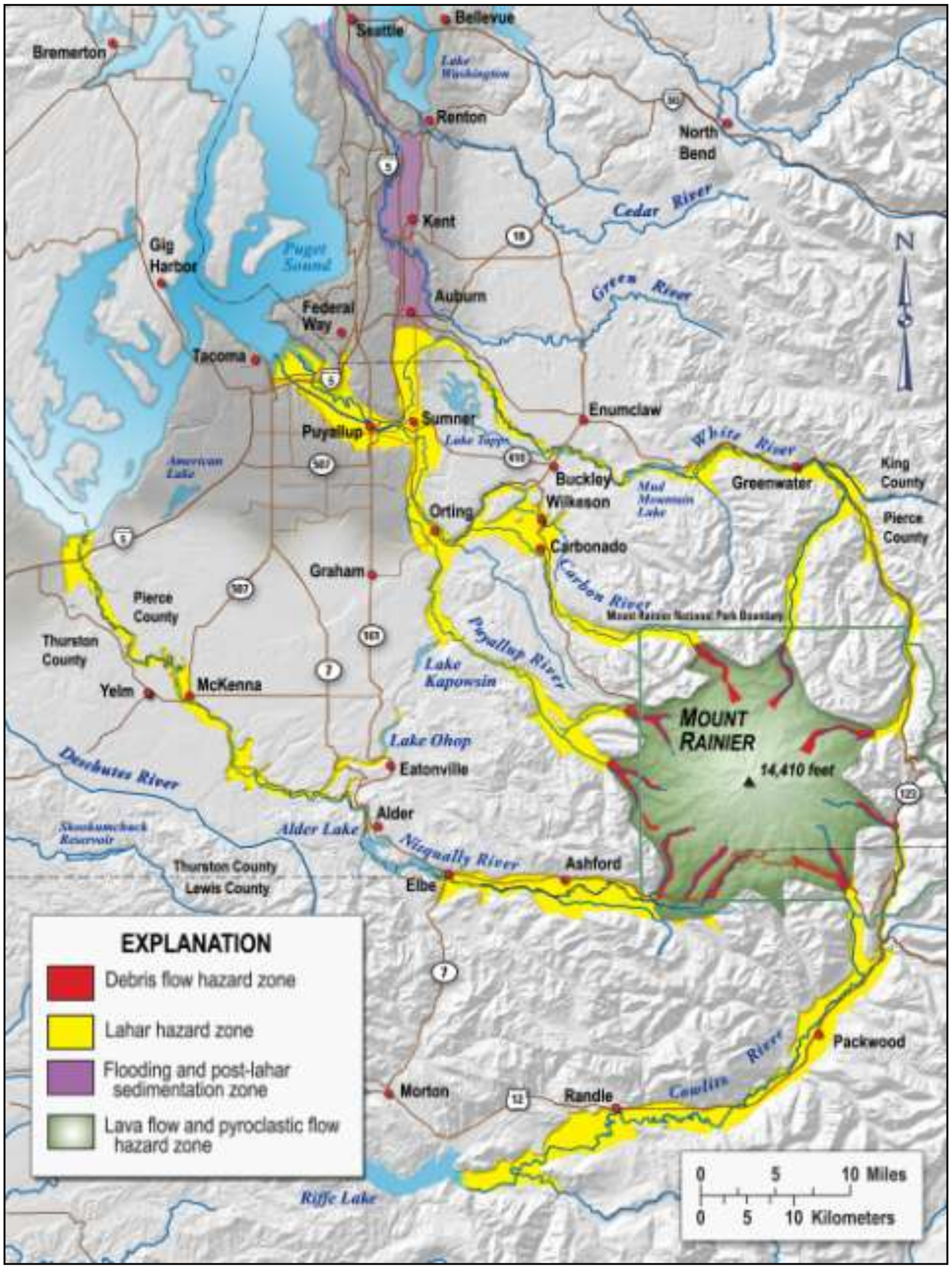
- Skagit County – Burlington, Concrete, Conway, Edison, Hamilton, La Conner, Mount Vernon, and Sedro Woolley, and the valleys of Baker and Skagit Rivers.
- Whatcom County - Deming, Everson, Ferndale, Glacier, Kulshan, Lynden, Nooksack, and Sumas, valleys of the North Fork Nooksack, Middle Fork Nooksack, and Nooksack Rivers, and the shores of Baker Lake.



Hazard zonation map for Mount Baker. Map modified from Gardner and others, 1995; U.S. Geological Survey Open-File Report 95-498.

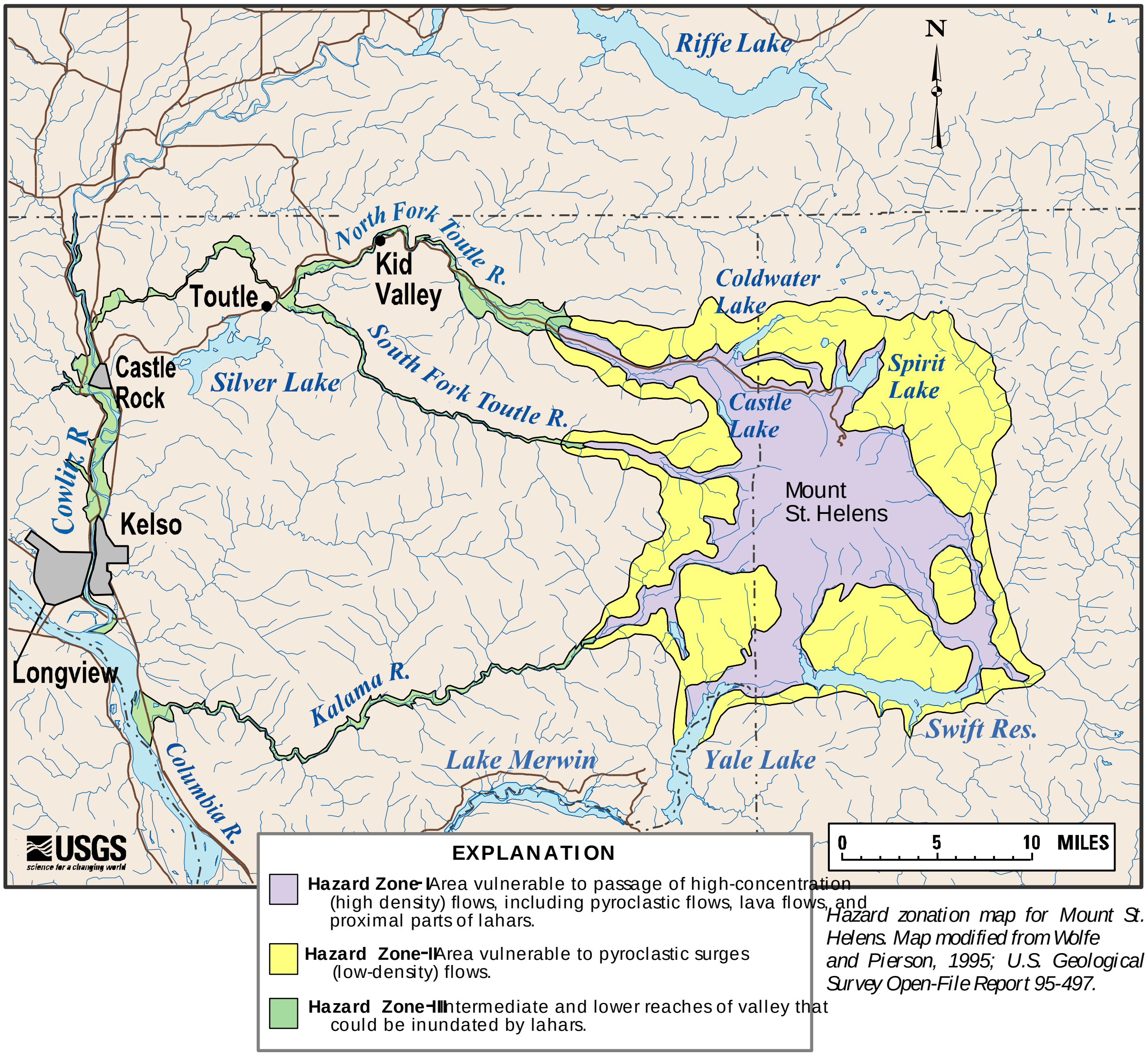
Mount Rainier

- King County – Auburn, Greenwater, Kent, Pacific, Seattle (Duwamish River), and Tukwila, and the valleys of the Duwamish, Green, and White Rivers.
- Lewis County – Packwood and Randle, and the Cowlitz River valley.
- Pierce County – Ashford, Buckley, Carbonado, Elbe, Fife, McKenna, Orting, Puyallup, South Prairie, Sumner, and Tacoma, and the valleys of the Carbon, Nisqually, Puyallup, and White Rivers.
- Thurston County – The Nisqually River valley.



Mount St. Helens

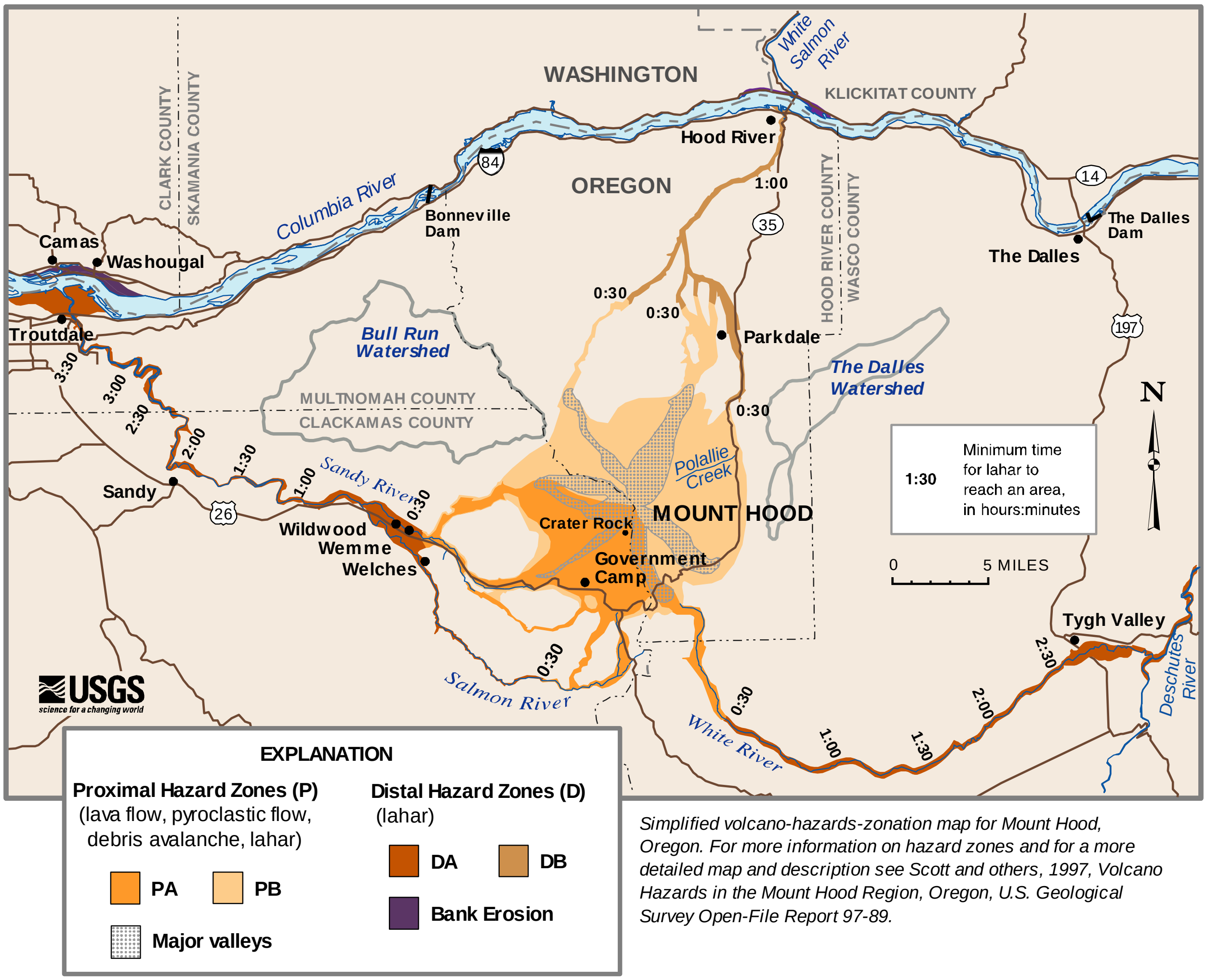
- Cowlitz County - Castle Rock, Kelso and Longview, and the valleys of the Cowlitz, Kalama, Lewis, and Toutle Rivers.
- Skamania County



Hazard zonation map for Mount St. Helens. Map modified from Wolfe and Pierson, 1995; U.S. Geological Survey Open-File Report 95-497.

Mount Hood, Oregon

- Clark County – Camas and Washougal, and nearby unincorporated areas.
- Klickitat County – Unincorporated areas near White Salmon.
- Skamania County.



Simplified volcano-hazards-zonation map for Mount Hood, Oregon. For more information on hazard zones and for a more detailed map and description see Scott and others, 1997, Volcano Hazards in the Mount Hood Region, Oregon, U.S. Geological Survey Open-File Report 97-89.

At-Risk State Agency Facilities

State Agency facilities identified as being at-risk to lahar (see table, page 33) were determined using geo-spacial software to match their location to the lahar hazard zone identified by the U.S. Geological Survey. The hazard zones chosen were for the worst-case, largest lahars possible (see narratives on each volcano, above).

State Agency Structures At Risk **VULNERABILITY ASSESSMENT**

Volcano:

	# of Facilities	Total Original Cost	Avg. Original Cost	Total Square Feet	Average Sq. Ft.
Owned:	122	$17,320,943	$141,975	261,305	2,142
	# of Essential Facilities	Total Original Cost	Avg. Original Cost	Total Square Feet	Average Sq. Ft.
	23	$9,963,952	$433,215	81,289	3,534
	# of Facilities	Total Monthly Rent	Avg. Monthly Rent	Total Square Feet	Average Sq. Ft.
Leased:	24	$186,448	$7,769	144,770	6,032
	# of Essential Facilities	Total Monthly Rent	Avg. Monthly Rent	Total Square Feet	Average Sq. Ft.
	1	$11,178	$11,178	8,463	8,463

State owned structures in hazard zone:

Function of at-risk buildings: Included in the state facilities potentially at-risk to the direct and indirect impacts of a worst-case lahar are the following:

- Campuses of the Rainier School for individuals with developmental disabilities, and of the Washington Soldiers Home and Colony.
- Arlington, Kendall Creek, Fallart Creek, North Toutle, Voights Creek, Soos Creek, and Klickitat hatcheries of the Department of Fish and Wildlife.
- Picnic, comfort, shelter, and other facilities at four parks operated by the State Parks and Recreation Commission, and a number of public access areas operated by the Department of Fish and Wildlife.
- Campuses of Skagit Valley College; Northwest Washington and Puyallup Research and Extension Centers operated by Washington State University; and Pack Forest operated by the University of Washington.
- Five weigh stations and detachment offices in Enumclaw and Burlington of the Washington State Patrol.

State critical facilities at risk within hazard zone:

Function of at-risk critical facilities: Included in the state facilities potentially at-risk to the direct and indirect impacts of a worst-case lahar are the following:

- Pump houses, chemical storage, power plants and emergency generators, and other facilities at state parks, state fish hatcheries, transportation department installations, WSU research centers, campuses of the Rainier School and Washington Soldiers Home, .
- Five weigh stations and detachment offices in Enumclaw and Burlington of the Washington State Patrol.

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